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Hazard Rating Ponderosa Pine Stands for Mountain Pine Beetles in the Black Hills

J.M. Schmid, S.A. Mata, and R.A. Obedzinski[1]

Even-age ponderosa pine stands in the Black Hills can be rated for infestation by the mountain pine beetle on the basis of mean stand diameter, stand density, and spacing. Tree spacing distances are derived for stands of different hazards and provide guidelines by which high-hazard stands can be converted to low-hazard stands.

Keywords: Mountain pine beetle, *Dendroctonus ponderosae*, ponderosa pine, *Pinus ponderosa*, hazard rating.

Determining the potential for infestation of pine stands by bark beetle populations allows forest managers to minimize future beetle-caused tree mortality. Hazard and risk rating methods have been developed for a number of *Dendroctonus* bark beetles in conifer stands in the West. Because the mountain pine beetle (MPB), *Dendroctonus ponderosae* Hopkins, is the most significant bark beetle in pine stands, a number of methods have been developed for it. The various methods have used: climatic zones (Safranyik et al. 1974); elevation-latitude, average age (years), and average diameter at breast height (d.b.h.) (Amman et al. 1977); periodic growth ratio (Mahoney 1978); crown competition and percent lodgepole pine basal area (Schenk et al. 1980); grams of sapwood per square meter of foliage (Waring and Pitman 1980), quadratic mean diameter and vigor (number of growth rings per centimeter) (Stuart 1984); climatic zones, elevation, average d.b.h, average age, and site (Hall 1985).

Nearly all of the hazard rating methods are for the MPB in lodgepole pine, *Pinus contorta* Douglas; only one has been developed for the MPB in ponderosa pine, *P. ponderosa* Lawson. For ponderosa pine, Stevens et al. (1980) developed a risk rating based on average tree diameter, stand density (basal area in ft^2 per acre), and stand structure (number of levels in the canopy). Single-storied stands with average tree diameter >10 in and with basal area >150 ft^2 per acre are considered high risk stands (Stevens et al. 1980). As average diameter and density decrease, potential risk also decreases (Stevens et al. 1980).

Other workers have characterized forest conditions associated with MPB-caused tree mortality but none of them have formulated the various stand and site factors into a hazard rating method. McCambridge et al. (1982) found basal area and site index were significantly higher in the area of highest tree mortality. Lessard (1982) identified stand structure (even-aged vs. uneven-aged) and tree diameter as important variables.

This note presents a method for hazard rating ponderosa pine stands in the Black Hills. The method gives a low, moderate, or high probability for the initial infestation of a stand by the MPB depending on: mean stand diameter of the stand in inches (in), stand density in terms of basal area per acre (ft^2 per acre), and tree spacing in feet (ft).

[1]*Entomologist, Forestry Research Technician, and Forester, Rocky Mountain Forest and Range Experiment Station. Headquarters is in Fort Collins, in cooperation with Colorado State University.*

Methods

To study the relationship between stand density and MPB-caused tree mortality in susceptible-size even-age ponderosa pine stands, a series of growing stock level (GSL) plots were installed in 11 different locations on the Black Hills National Forest in South Dakota. Plot installation began in 1985 and ended in 1992. Each series usually consisted of four 2.5-acre plots, of which three plots were cut either to GSLs of 60, 80, and 100, or to 80, 100, and 120. The fourth plot, uncut, served as a control. The plots were usually cut within one year of installation. Leave trees within the cut plots were selected on the basis of diameter, spacing, crown development, and apparent good health. Tree selection emphasized leaving the best, largest trees as evenly spaced as possible. Tree selection favoring the larger trees caused the average stand diameter after cutting to be about 1 in greater than the average stand diameter before cutting.

Since installation in 1989 and in 1991, two sets of plots—the White House Gulch plots and the Boy Scout plots located about 10 miles northwest of Custer, South Dakota—were exposed to a natural MPB epidemic (Schmid and Mata 1992, J.M. Schmid 1993, unpublished information). MPB-caused tree mortality in the control plot[2] of the White House Gulch plots has been greater than in the cut plots from 1989 through 1992 except for the GSL 116 plot in 1992 when wind damage created a primary focus tree which subsequently caused attacks on 13 surrounding trees (Schmid and Mata 1992, J.M. Schmid 1993, unpublished information).

The Boy Scout plots have exhibited patterns of tree mortality similar to those of the White House Gulch plots since they were installed in 1991; tree mortality in the uncut control (GSL 177) being greater than in the cut plots (J.M. Schmid 1993, unpublished information).

Information on tree spacing for GSL 60, 80, 120, and ≥140 stands was derived from the plots at the 11 locations and not just from the White House Gulch and Boy Scout plots. The area of each plot in square feet was divided by the number of leave trees after cutting to derive the number of square feet surrounding each tree. The square root of this area value was then taken to derive the amount of distance in feet (spacing) between the residual trees. Tree spacing calculated in this manner obviously assumes the leave trees are all equally spaced which in practice they are not. The spacing distance for each plot for each GSL was then plotted against its respective quadratic mean diameter (in) before the plot was cut and a regression line derived for each GSL. We used quadratic mean diameter before cutting because foresters could derive this information from Stage II stand inventory data—part of the essential information on hand when planning silvicultural activities. The regression line for the GSL 120 will probably be modified in the future as more plot data become available.

Results and Discussion

Beetle-caused tree mortality has not occurred in the White House Gulch GSL 60 and GSL 80 since cutting (Schmid and Mata 1992, J.M. Schmid 1993, unpublished information). No tree mortality has been evident in the Boy Scout GSLs 60, 80, and 100 since installation although two pitchouts were observed in the GSL 80 in 1993 (J.M. Schmid 1993, unpublished information). Therefore, we consider stands with GSLs ≤80 or all stands with uniform tree spacing greater or equal to the GSL 80 regression line in figure 1 to be low-hazard stands. The smallest spacing between residual trees in low-hazard stands is thus described by the equation for the GSL 80 regression line ($S = 1.75*DBH + 1.61$ where S equals the distance in feet and DBH equals the quadratic mean diameter of the uncut stand in inches).

Beetle-caused tree mortality averaged about 15 trees per year in the White House control (GSL 148) during 1989 to 1992 but only 4 trees were attacked in 1993 as the epidemic declined (Schmid and Mata 1992, J.M. Schmid 1993, unpublished information). Tree mortality in the Boy Scout control plot (GSL 177) has decreased from 8 trees in 1991 to 2 trees and 4 pitchouts in 1993 (J.M. Schmid 1993, unpublished information). We consider stands with GSL ≥140 to be high-hazard stands because of the observed mortality. Moreover, we have also observed beetle-caused tree mortality in the Crook Mountain GSL 120 plot in the northern Black Hills and currently believe the threshold for high-hazard stands is less than GSL 140 and probably about GSL 120 (see Schmid and Mata 1992). The greatest spacing between trees in high hazard stands is thus described by the equation for the regression line for GSL 120 stands ($S = 1.5*DBH + 1.0$). All stands with spacing less than or equal to the GSL 120 regression line in figure 1 are considered high-hazard stands.

As discussed in Schmid and Mata (1992), the density threshold for high-hazard stands depends a great deal on the size of the area under consideration. An MPB-infested spot may have a basal area density of ≥150 ft^2 per acre (Sartwell and Stevens 1975) when

[2]*Some readers will notice a discrepancy between the GSL values for two White House Gulch plots in this paper as compared to those reported in Schmid and Mata (1992). Schmid and Mata erroneously reported the control plot = GSL 128 and the GSL 100 plot = GSL 100. The correct values are GSL 148 for the control plot and GSL 116 for the other plot. Schmid and Mata apologize for the error.*

only the immediate area of infested trees is considered. If the area considered is substantially larger, i.e., 2.5 acres, then basal area density within the 2.5 acres may average considerably less than 150 ft^2 per acre. Uncut stands are rarely homogeneous and a stand such as the White House Gulch control with an overall average of 148 ft^2 per acre in 1989 may have a range in basal area from 100 to more than 200 ft^2 per acre in some 0.1-acre parcels within it. MPB infestations may be highly associated with these higher density spots within the stand as Sartwell and Stevens (1975) found, but we believe it is more practical to consider the overall average value of a stand because this value is more likely to be obtained from inventory surveys.

Tree mortality was observed in the White House Gulch GSL 116 plot in 1991 and 1992 but has not been observed in the Boy Scout GSL 100 (J.M. Schmid 1993, unpublished information). The White House Gulch plot had two MPB-infested trees on the periphery of the plot in 1991 and 14 MPB-attacked trees in the central portion of the plot in 1992. The 1992 MPB-attacked trees were caused by wind damage to a forked-top tree which became a primary focus tree and subsequently caused the infestation of 13 adjacent trees (J.M. Schmid 1993, unpublished information). Because the mortality seemed to be transitory, we consider this GSL 116 stand to be moderately hazardous. Therefore, stands with GSLs greater than GSL 80 but less than GSL 120 are considered moderately hazardous. Restated in terms of spacing, stands where tree spacing is greater than that described by the equation $S = 1.50*DBH + 1.0$ but less than that described by the equation $S = 1.75*DBH + 1.61$ are moderate-hazard stands.

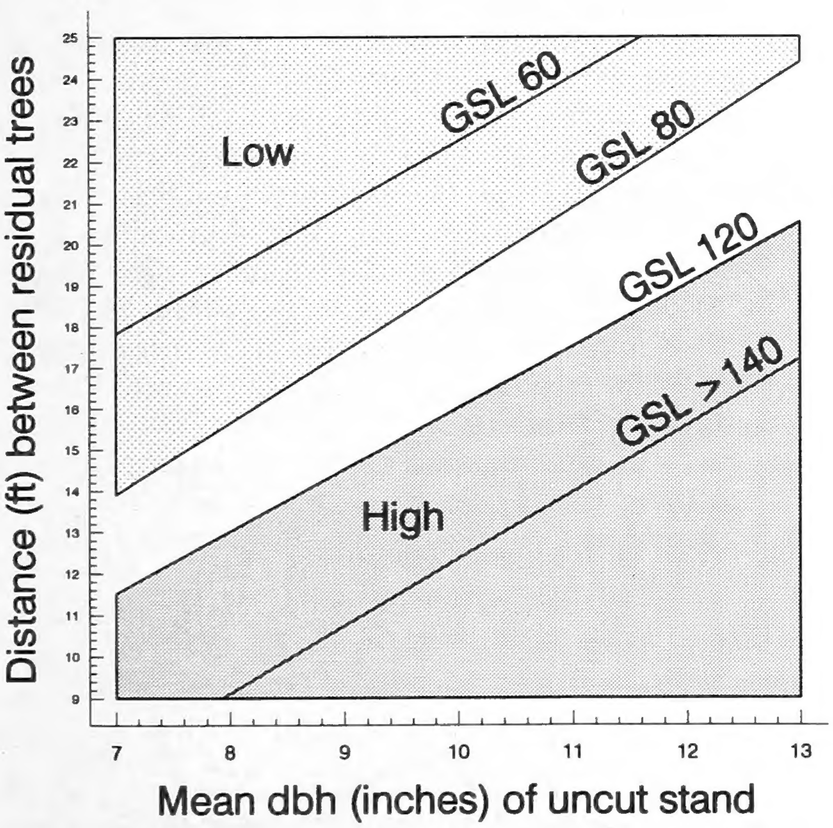

Figure 1. — Low-, moderate-, and high-hazard levels for the infestation of ponderosa pine in the Black Hills by the mountain pine beetle.

The upper and lower limits for moderate-hazard stands are derived primarily by default. The limits seem relatively close together and we attribute this to the paucity of plots available for derivation of the regression line for the GSL 120. Although mortality has been observed in the White House Gulch GSL 116 plot, plots with GSLs of 90 or 110 or other intermediate values have not been installed. Therefore, more definitive limits for the moderate-hazard stands will have to be determined in the future. We expect to derive this information by installing additional plots at different GSL levels than in our original experimental design, and by allowing the current plots to grow to higher levels, and then maintaining them at those levels, i.e., GSL 80 stands will be allowed to grow to GSL 90 and then held at that level.

Although we believe the low- and high-hazard categories are generally well defined, we also believe the lower limit of the low-hazard category (i.e., GSL 80 regression line) and the upper limit of the high-hazard category (i.e., GSL 120 regression line) may well change when future results are compiled. For example, low-hazard stands may include GSL 90 or GSL 100 stands. And it may be possible to create a low-hazard, high-density stand (GSL 120–130) if the stand is partially cut with emphasis on uniform spacing.

As more data is gathered, two hazard rating methods may evolve: one for unmanaged stands and one for managed stands. A three-category (low-moderate-high) hazard rating method for unmanaged even-age stands might well become a two-category (low and high but no moderate category) hazard method for managed even-age stands because cutting practices that emphasize uniform spacing should reduce the susceptibility of stands currently classified in the moderate-hazard category. Whatever the eventual method and the category limits, the forest manager must remember that partially cut ponderosa pine stands can grow rather quickly into moderate- to high-hazard stands. For example, a GSL 80 stand, considered a low-hazard stand today, may become a high-hazard stand in 10 to 20 years depending on its growth rate (Schmid 1987). Hazard ratings should be used as a warning of potential MPB problems when stand densities are high but should not lull managers into ignoring stands when stand densities are low.

We also want to emphasize that our hazard rating method was developed for relatively homogeneous even-age stands. It may be applicable with minimal modification in other parts of the range of ponde-

rosa pine where stand conditions are similar. However, the method may need more modification to be applicable in locations where stand conditions are represented by low density but uniformly-spaced even-age trees intermixed with clumps of high density trees or where stands are uneven-age.

One word of caution when using the hazard rating figure. The user cannot assume the average stand diameter before cutting will equal the average stand diameter after cutting. For example, if the user wants to convert a 10 in stand of GSL 140 (high-hazard) into a stand of GSL 80 (low-hazard), figure 1 indicates the spacing of trees after cutting should average about 19 ft. Based on the average spacing of 19 ft, the number of trees per acre would be about 121. Using 121 trees per acre and the basal area of a 10 in tree, the user would determine that the basal area in the residual trees would be about 66 ft^2. Because the residual basal area of 66 ft^2 per acre would be considerably less than the desired 80 ft^2 per acre, the user would think the spacing guideline was incorrect. However, the user erroneously assumed the average stand diameter before cutting (10 in) would equal the average stand diameter after cutting (10 in). As noted in the methods section, if tree selection favors larger trees, the average stand diameter after cutting will be about 1 in greater than the average stand diameter before cutting. This effect has been incorporated into the regression equations for the thinned GSLs so the user must accept the spacing distance as yielding the desired GSL (GSL 80 in this case). Obviously, if tree selection does not favor the larger trees, the spacing distance will not yield the desired GSL.

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